MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

EEL2216 – CONTROL THEORY

(All sections / Groups)

2^{nd} JUNE 2016
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SEVEN** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) A feedback control system is shown in Figure 1.1. Assume zero initial condition,

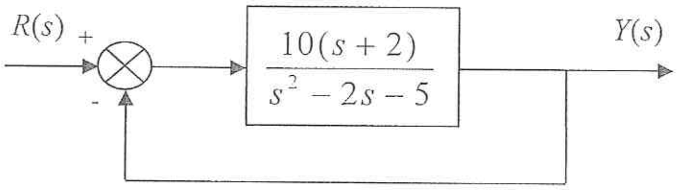

Figure 1.1

i. Find the closed-loop transfer function, $Y(s)/R(s)$. [2 marks]
ii. Determine the output, $Y(s)$ when $R(s)$ is a unit step input. [2 marks]
iii. Based on the result in part (a)(ii), compute $y(t)$. [5 marks]

(b) Write the modeling equation in Laplace transform for the translational mechanical system shown in Figure 1.2. [4 marks]

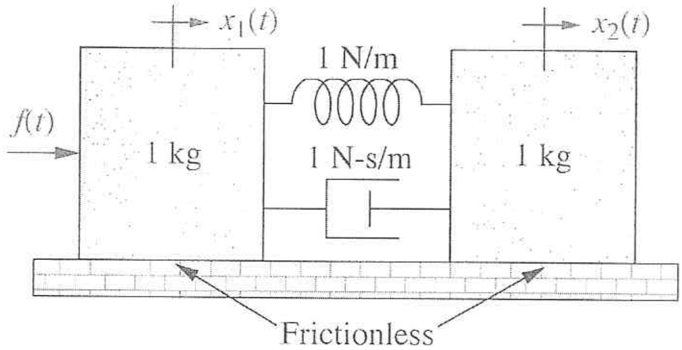

Figure 1.2

(c) Derive the transfer function, $T(s) = C(s)/R(s)$ of the signal flow graph shown in Figure 1.3 by using Mason's rule. [12 marks]

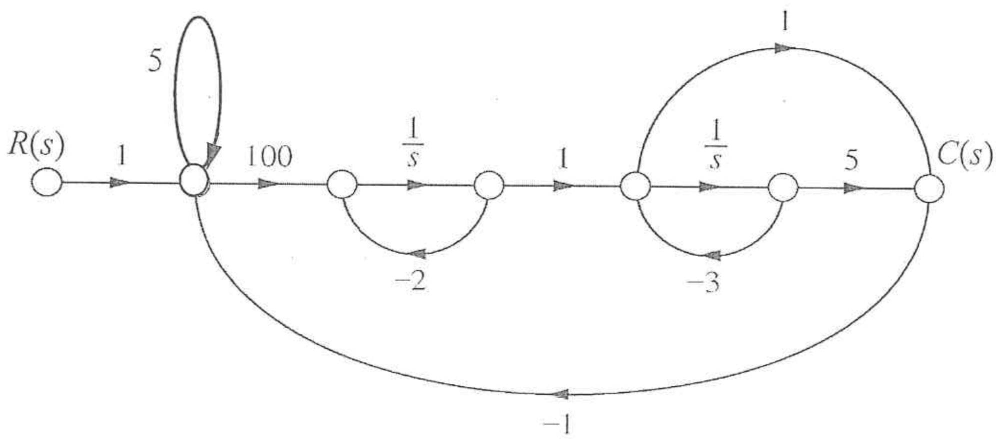

Figure 1.3

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Question 2

(a) Consider a negative unity feedback system shown in Figure 2.1.

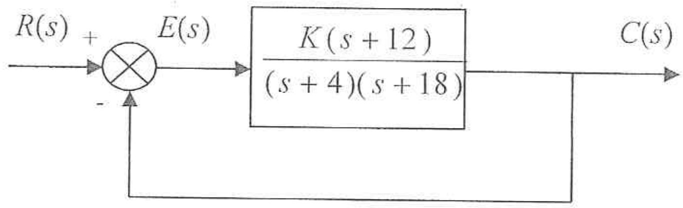

Figure 2.1

i. State the system type and determine the value of K for a 10% error in the steady state. [5 marks]

ii. Given $K = 6$, evaluate if the system is underdamped, critically damped or overdamped. [5 marks]

(b) A negative feedback system has a loop transfer function given by,

$$G(s)H(s) = \frac{K(s+1)}{(s-1)(2s^2+5)}.$$

i. Find the starting and ending points, root loci on real axis, angle of departures, and asymptotes at infinity. [10 marks]

ii. Sketch the root loci. [3 marks]

iii. Based on the root loci, analyse the overall system stability when the gain, K value increases from $0 \rightarrow \infty$. [2 marks]

Continued...

Question 3

(a) As a control engineer, you are always required to determine the stability of a closed loop system. One unique method to measure stability is the use of Nyquist stability criterion. Describe in your own words, the definitions of:

i. Nyquist sampling theorem. [3 marks]
ii. Phenomenon of aliasing in sampling process. [2 marks]

(b) A processing plant can be represented by a block diagram as shown in Figure 3.1.

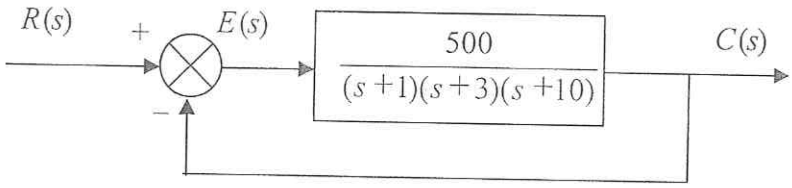

Figure 3.1

i. Simplify the loop transfer function and rewrite it in terms of $j\omega$. [4 marks]
ii. Determine the magnitude response of the loop transfer function. [3 marks]
iii. Determine the phase response of the loop transfer function. [3 marks]
iv. Calculate the real and imaginary crossing points for the polar plot. [6 marks]
v. Sketch the Nyquist diagram. [4 marks]

Continued...

Question 4

(a) For a compensated system, choose a suitable controller and state **ONE** reason how it can fulfill each of the specifications below separately:

i. the steady state error needs to be zero. [2 marks]
ii. the system requires no additional amount of energy supply. [2 marks]
iii. the settling time is reduced and the step error constant is increased. [2 marks]

(b) A system with a plant transfer function, $G(s) = \dfrac{1}{(s+3)(s+5)}$ is shown in Figure 4.1.

Given that a PD controller has a transfer function of $K_{PD}(s) = k_a s + k_b$ and PI controller has a transfer function of $K_{PI}(s) = \dfrac{k_c s + k_d}{s}$.

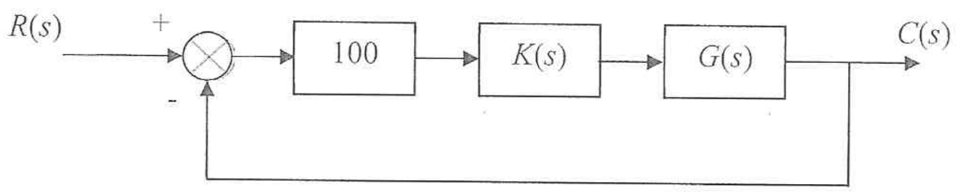

Figure 4.1

i. Design the $K(s)$ as a PD controller if the system requires a damping ratio, $\zeta = 0.8$ and an angular frequency, $\omega_n = 15$ rad/s. [6 marks]
ii. Design the $K(s)$ as a PI controller if the system requires a steady-state error less than 0.05 for a unit ramp input without changing the transient response. [9 marks]
iii. What are the steps to follow if you need to design a PID controller in a single system? [4marks]

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Appendix - Laplace Transform Pairs (continued)

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \quad (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\ \ (\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper